

CIRCUIT, INCLUDING FEEDBACK, FOR REDUCING  
DC-OFFSET AND NOISE PRODUCED BY AN AMPLIFIER

Related Application

This is a continuation of U.S. Patent Application Serial No. 09/439,240, filed on November 12, 1999, and entitled "Circuit Comprising Means For Reducing DC-Offset And Noise Produced By An Amplifier"

Field of the Invention

The present invention is directed to amplifier circuits and, more specifically, to amplifier circuits susceptible to problems involving DC offsets and noise.

Background of the Invention

Such a circuit is known from the general state of the art as shown in Figure 1. The known circuit comprises an amplifier AMP having a differential input 5;6 comprising an input node 5 and an input node 6, and a differential output 7;8 comprising an output node 7 and an output node 8. The circuit further comprises an input chopper  $CHP_i$  arranged in cascade in between a differential input 1;2 of the circuit and the differential input 5;6 of the amplifier AMP, and an output chopper  $CHP_o$  synchronised with the input chopper  $CHP_i$ , which output chopper  $CHP_o$  is arranged in cascade in between the differential output 7;8 of the amplifier AMP and a differential output 3;4 of the circuit. The operation of the known circuit is as follows. An input signal  $V_{in}$  is supplied to the differential input 1;2. In response to the input signal  $V_{in}$  an output signal  $V_{out}$  is delivered to the differential output 3;4. The input chopper  $CHP_i$  is arranged for alternately coupling either input terminals 1 and 2 of the differential input 1;2 to respectively input nodes 5 and 6 of the differential input 5;6 during a first phase  $PHI_1$ , or input terminals 1 and 2 of the differential input 1;2 to respectively input nodes 6 and 5 of the differential input 5;6 during a second phase  $PHI_2$ . The output chopper  $CHP_o$  is arranged for alternately coupling either output nodes 7 and 8 of the differential output 7;8 to respectively output terminals 3 and 4 of the differential output 3;4 during a first phase  $PHI_1$ , or output nodes 7 and 8 of the differential output 7;8 to respectively output terminals 4 and 3 of the dif-

ferential output 3;4 during a second phase  $\text{PHI}_2$ . The input signal  $V_{in}$  is converted to the output signal  $V_{out}$  in virtually the same manner as in the case that the input chopper  $\text{CHP}_i$  and the output chopper  $\text{CHP}_o$  would not have been present. However by the presence of the input chopper  $\text{CHP}_i$  and the output chopper  $\text{CHP}_o$  the offset produced by the amplifier AMP, which  
5 offset is denoted as  $V_{os}$  in Figure 1, is eliminated. Also the noise produced by the amplifier AMP is significantly reduced for frequencies lower than the switching frequency of the switches in the input chopper  $\text{CHP}_i$  and the output chopper  $\text{CHP}_o$ . For the purpose of reducing the noise produced by the amplifier AMP the aforementioned switching frequency must be as high as possible.

10 A problem of the known circuit is that for a high switching frequency the so-called charge injection caused by the switches of the input chopper  $\text{CHP}_i$  and the output chopper  $\text{CHP}_o$  causes a DC-offset in the output signal  $V_{out}$ . Thus with the known circuit an optimal DC-offset reduction can only be accomplished if the switching frequency is low. In that case the noise reduction is not optimal. On the other hand an optimal noise reduction is  
15 accomplished if the switching frequency is high. In that case however the DC-offset reduction is not optimal. Thus, with the known circuit, an optimal DC-offset reduction and an optimal noise reduction can not be accomplished at the same time.

## Summary of the Invention

The present invention is directed to overcoming the above-mentioned challenges and others related to amplifier offset and noise. The present invention is exemplified in a number of implementations and applications, some of which are summarized below.

5        One aspect of the present invention is directed to a circuit including an amplifier producing a DC-offset and noise having an input for receiving an input signal from an input of the circuit, and an output for delivering an output signal to an output of the circuit; means for reducing the DC-offset and the noise produced by the amplifier; and feedback means for further reducing the DC-offset produced by the amplifier.

10        In a more particular example embodiment of the present invention, the means for reducing the DC-offset and the noise produced by the amplifier comprises an input chopper arranged in cascade in between the input of the circuit and the input of the amplifier, and an output chopper synchronized with the input chopper. The output chopper is arranged in cascade in between the output of the amplifier and the output of the circuit. The input chopper and the output chopper can be operative as high frequency  
15        choppers.

In another more particular example embodiment of the present invention, feedback means comprises switching means for short-circuiting the input signal under control of a start-up signal; and means for adding back a sampled output signal to the amplifier for adapting  
20        the DC-offset of the amplifier. Also, the means for adding back the sampled output signal to the amplifier can include: an analog to digital converter with an input coupled to the output of the circuit, and with an output; a digital processing circuit with an input coupled to the output of the analog to digital converter, and an output; and a digital to analog converter with an input coupled to the output of the digital processing circuit, and  
25        an output coupled to the amplifier for adapting the DC-offset of the amplifier.

The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. Other aspects include methods for using and for manufacturing such a thyristor and to memory arrangements employing the above-characterized thyristor construction. The figures and  
30        detailed description that follow more particularly exemplify these embodiments.

### **Brief Description of the Drawings**

The invention may be more completely understood in consideration of the detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

5        Figure 1 is a circuit diagram of a known circuit for reducing DC-offset and noise in an amplifier circuit;

      Figure 2 is a circuit diagram of an example embodiment according to the present invention; and

10       Figure 3 is a circuit diagram of another example embodiment according to the present invention.

      While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not necessarily to limit the invention to the particular embodiments described. On the contrary, the  
15       intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

### Detailed Description

Figure 2 shows a circuit diagram of a first embodiment of a circuit according to the invention. The circuit comprises an amplifier AMP having input nodes 5 and 6 for receiving an input signal  $V_{in}$  which is available between input terminals 1 and 2 of the circuit, and output nodes 7 and 8 for delivering an output signal  $V_{out}$  to output terminals 3 and 4 of the circuit. For the purpose of reducing the DC-offset and the noise produced by the amplifier AMP the circuit is further provided with an input chopper  $CHP_i$ , a further input chopper  $CHP_{fi}$ , an output chopper  $CHP_o$ , and a further output chopper  $CHP_{fo}$ . The input chopper  $CHP_i$  and the further input chopper  $CHP_{fi}$  are cascaded in between the input terminals 1 and 2 and the input nodes 5 and 6, whereby the further input chopper  $CHP_{fi}$  is cascaded in between the input terminals 1 and 2 and the input chopper  $CHP_i$ . The output chopper  $CHP_o$  and the further output chopper  $CHP_{fo}$  are cascaded in between the output nodes 7 and 8 and the output terminals 3 and 4, whereby the further output chopper  $CHP_{fo}$  is cascaded in between the output chopper  $CHP_o$  and the output terminals 3 and 4.

The operation of the circuit is as follows. The input chopper  $CHP_i$  and the output chopper  $CHP_o$  receive a high frequency clock signal which is available between a first clock terminal  $CLK_H$  and a reference terminal GND. By so doing the DC-offset and the noise produced by the amplifier AMP is significantly reduced. For obtaining an optimal noise reduction the frequency of the high frequency clock signal is as high as possible. In principle the DC-offset produced by the amplifier AMP would be virtually cancelled. However the so-called charge injections caused by the switches in the input chopper  $CHP_i$  and the output chopper  $CHP_o$  cause a DC-offset at the output of the output chopper  $CHP_o$ . To remove the DC-offset at the output of the output chopper  $CHP_o$  the further input chopper  $CHP_{fi}$  and the further output chopper  $CHP_{fo}$  receive a low frequency clock signal which is available between a second clock terminal  $CLK_L$  and the reference terminal GND. Because the further input chopper  $CHP_{fi}$  and the further output chopper  $CHP_{fo}$  operate at a relatively low frequency the further input chopper  $CHP_{fi}$  and the further output chopper  $CHP_{fo}$  do not introduce a DC-offset. The noise reduction of the further input chopper  $CHP_{fi}$  and the further output chopper  $CHP_{fo}$  is not optimal. This causes however no problem since the noise produced by the

amplifier AMP is already cancelled by the input chopper  $CHP_i$  and the output chopper  $CHP_o$ . Thus the combination of the input chopper  $CHP_i$ , the output chopper  $CHP_o$ , the further input chopper  $CHP_{fi}$  and the further output chopper  $CHP_{fo}$  guarantee an optimal DC-offset reduction and also an optimal noise reduction of the amplifier AMP. It is to be stated that though the  
5 frequency of the low frequency clock signal must be relatively low, it must not be chosen unnecessary low since the maximum transfer frequency of the circuit is in practice limited to half the value of the low frequency clock signal.

Figure 3 shows a circuit diagram of a second embodiment of a circuit according to the invention. An important difference with respect to the first embodiment is that the  
10 circuit does not comprise the further input chopper  $CHP_{fi}$  and the further output chopper  $CHP_{fo}$ . The cancellation of the DC-offset at the output of the output chopper  $CHP_o$  is carried out in a different manner. This has the advantageous effect that the maximum transfer frequency of the circuit is much higher. The circuit is provided with a switch SW connected in between the input terminals 1 and 2. A control electrode of the switch SW is connected to a  
15 control terminal  $ST_{UP}$ . The circuit further comprises an analog to digital converter ADC with an input connected to the output terminal 3, and with an output; a digital processing circuit DPC with an input connected to the output of the analog to digital converter ADC, and an output; and a digital to analog converter DAC with an input connected to the output of the digital processing circuit DPC, and an output coupled to the amplifier AMP.

The operation of the circuit is as follows. At the start-up of the circuit the inputs  
20 of the input chopper  $CHP_i$  is short-circuited under control of a start-up signal  $V_{ST}$  which is available between the control terminal  $ST_{UP}$  and the reference terminal GND. The DC-offset at the output of the output chopper  $CHP_o$  is measured and fed back to the amplifier AMP in order to adapt the DC-offset of the amplifier AMP. This measurement is in fact accomplished by  
25 sampling the signal at the output of the output chopper  $CHP_o$  during the start-up of the circuit. The sampling is accomplished in the digital domain in order to avoid the problem of leakage of a necessary sampling capacitor in the case that the sampling would be accomplished in the analog domain. For this reason the analog to digital converter ADC converts the analog output signal  $V_{out}$  to a digital representation of the analog output signal  $V_{out}$ . The digital sampling is  
30 then performed by the digital processing circuit DPC. The digital output signal delivered by

the digital processing circuit DPC is then converted to an analog signal by the digital to analog converter DAC for adapting the DC-offset of the amplifier AMP. The feedback loop created by the analog to digital converter ADC, the digital processing circuit DPC and the digital to analog converter DAC is active until the DC-offset at the output 3;4 of the circuit is virtually zero. Then the start-up signal  $V_{ST}$  switches off the switch SW and the circuit is then ready for transferring the input signal  $V_{in}$  to the output signal  $V_{out}$ . The adaption of the DC-offset of the amplifier AMP can for instance be accomplished by controlling a current of one transistor of a differential input pair within the amplifier AMP. By way of example the differential signal from the output chopper  $CHP_o$  is transferred to a single-ended output signal  $V_{out}$  by a further amplifier  $AMP_f$ .

If the circuit does not have to operate continuously the "start-up procedure" can be repeated now and then, for instance by doing a re-calibration after each sampling performed in the digital domain. This has the advantage that a potential DC-offset due to a temperature change after the completion of the start-up, is avoided.

Though varies signals are indicated as differential signals with regard to the first and the second embodiments the invention can also be carried out with single-ended signals. So for instance in Figure 2 the input terminal 2 and/or the output terminal 4 could also be connected to the reference terminal GND. The inventive circuit can be implemented with discrete components as well as with an integrated circuit. All types of transistors can be used.